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A Study on Supply Chain Information Integration of Commodity Circulation Based on Grid

Jiang Yanhui[a], Li Xian[a*]

[a]*Business School, Hunan University, Changsha, China*

Abstract

The application of grid technology in supply chain information integration is necessary to adapt to the change of competitive environment. The purpose of applying grid technology in Supply Chain integration is to link up all the existing resources and thus to improve the operation efficiency of the supply chain. Take supply chain information integration of commodity circulation as an example. This paper comparatively analyzes the operation efficiency of supply chain integration system under traditional mode and under grid environment with time Petri nets. The results show the superiority of the supply chain integration system under grid environment.

Keywords: Grid; Supply Chain; Information Integration; Time Petri Nets

1. Introduction

With the coming of economic globalization, modern enterprises are facing increasingly fierce and complex market environment, and the uncertainty and personalization of customer demand are also increasing. The traditional supply chain management has obviously not adapted to the current competitive environment, so that some problems emerged in enterprises, such as "bullwhip effect ". To solve these problems, the fundamental solution is implementing integrated supply chain management. Grid is emerging as a new technology comprehensively integrated of the new generation Internet. Applying grid to the supply chain system can greatly improve the information sharing degree of the node enterprises in the supply chain [1].The research on Integrated Supply Chain is a hot topic at home and

* Jiang Yanhui. Tel.: 13637400234.
E-mail address: huihui0733@163.com.

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abroad [2]. Also, some researchers have devoted their efforts to the supply chain combing with grid. Forza et al. proposed that the integration of I&CTs (Information & Communication Technology) would inevitably involve promoting the information transmission among the enterprises of the supply chain and support transformation from "local optimization" to "supply chain optimization"[3]. Wang et al. analyzed the influence of grid computing in SCM [4]. Zhao and Tan et al. put forward the model of SCMS based on grid computing [5].

However, very few researched to what extent applying grid technology in supply chain integration would improve the information sharing degree of the node enterprises in the supply chain. this paper uses time Petri nets analyzing the information integration efficiency in commodity circulation under traditional mode compared with that under grid environment.

2. Time Petri nets

Time Petri Nets were introduced in Merlin [6]. A TPN is a tuple (P, T, B, F, M_0, SI) where 1) $P = \{p_1, p_2, ..., p_m\}$ is a finite nonempty set of places, 2) $T = \{t_1, t_2, ..., t_n\}$ is a finite nonempty set of transitions, 3) $B : P \times T \rightarrow N$ is the backward incidence function, 4) $F : T \times P \rightarrow N$ is the forward incidence function, 5) M_0 is a the initial marking, 6) SI is a mapping called static interval. $\forall t \in T, SI(t) = [SEFT(t), SLFT(t)]$, where $SEFT(t)$ is the static earliest firing time and $SLFT(t)$ the static latest firing time.

A state of a TPN is a pair $S = (M, I)$ where 1) M is a marking, 2) I is a firing interval set which is a vector of possible firing times. The number of entries in this vector is given by the number of the transitions enabled by marking.

Time Petri Nets extends Petri Nets with timing constraints on the firings of transitions. Time Petri Nets is used to analyze the timing property of system. In order to illustrate the difference in efficiency between traditional mode and grid environment, this paper analyzes the supply chain operating time/efficiency under grid environment with Time Petri Nets. Through the comparisons of the efficiency, we can prove what the better method is.

3. Modeling with time Petri nets

In the grid environment, the operation of supply chain in commodity circulation is scheduled unifiedly by the supply chain information integration platform. Fig. 1 and Fig. 2 show the principle.

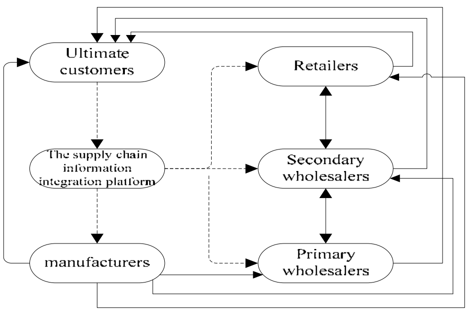

Fig. 1. Principle of supply chain under grid environment.

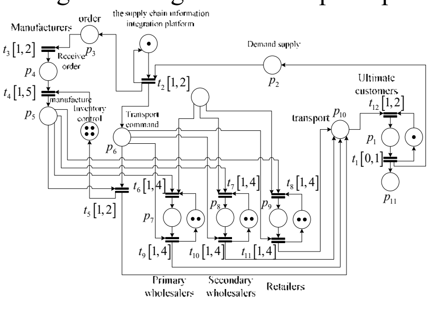

Fig. 2. Operation process of integrated supply chain under grid environment

In Fig. 1, $p_i (i = 1,2,...)$ indicates places, $t_j (j = 1,2,...)$ indicates transitions. $t_j[\alpha, \beta]$ indicates that when transition t_j is enabled in marking M , it will, at least, pass α unit time to happen; if there is no other transition happening to make t_j unable, transition t_j will inevitably happen in β unit time at the latest.

Give all places and transitions practical meaning, and they are

places-- p_1 indicates "ultimate customer", p_2 indicates "supply demand", p_3 indicates "order", p_4 indicates "receive order", p_5 indicates "enterprise inventory", p_6 indicates "transportation command", p_7, p_8, p_9 indicate "intermediaries inventory", p_{10} indicates "supply department", p_{11} indicates "customer consumption";

transitions-- t_1 indicates "customer consumption", t_2 indicates "send out transport command", t_3 indicates "receive order", t_4 indicates "manufacture", t_5 indicates "transportation of enterprise warehouse", t_6, t_7, t_8 indicate "warehouse inbound in intermediaries at all levels", t_9, t_{10}, t_{11} indicate "warehouse outbound in intermediaries at all levels", t_{12} indicates "customer receiving commodity".

Setting p_1 (ultimate customer) as the initial point, that is

$$M_0 = [M_0(p_1), M_0(p_2), \cdots, M_0(p_{16})] = [1, 0, 0, \cdots] \tag{1}$$

And p_{11} is the final of the process.

According to Fig.2, the relation of manufacturers, primary wholesalers, secondary wholesalers and retailers isn't the affiliation but a equal, parallel relationship. All the enterprises are scheduled uniformly by the by the supply chain information integration platform and receive the command from it to transport commodities. Because of the parallel relationship, we can optimize for the structure. Through optimization algorithm, we can find out optimal transport route and supply customers in the shortest possible time, and improve the efficiency.

4. Model analysis

This section makes scenario analysis to six situations: (1)intermediaries at all levels keep inventory, (2)primary wholesalers keep inventory, (3)secondary wholesalers keep inventory, (4)retailers keep inventory, (5)manufacturers keep inventory, (6)all the warehouses keep no inventory.

(1) Intermediaries at all levels keep inventory

Under grid environment, the marking of Petri nets in the case that intermediaries at all levels keep inventory is

$$M_0 = \begin{bmatrix} M_0(p_i) = 1 & & i = 1 \\ M_0(p_i) = 1,2 & & i = 7,8,9 \\ M_0(p_i) = 1,4 & & i = 5 \\ M_0(p_i) = 0 & i = the \quad rest \;, \quad and & i \le 11 \end{bmatrix} \cdot$$

Because of the competitive relation between the transitions, there are several transport routes. The demand sent out by ultimate customers will be supplied after the following transitions:

$t_1\,[0,1], t_2\,[1,2], t_5\,[1,2], t_{12}\,[1,2]$

$t_1\,[0,1], t_2\,[1,2], t_9\,[1,4], t_{12}\,[1,2]$

$t_1\,[0,1], t_2\,[1,2], t_{10}\,[1,4], t_{12}\,[1,2]$

$t_1\,[0,1], t_2\,[1,2], t_{11}\,[1,4], t_{12}\,[1,2]$

Due to the timing constraints of $t_5\,[1,2]$, the minimum and maximum are the same, and they are $[3,7]$.

(2)Only primary wholesalers keep inventory

Under grid environment, the marking of Petri nets in the case that intermediaries at all levels keep inventory is

$$M_0 = \begin{bmatrix} M_0(p_i) = 1 & & i = 1 \\ M_0(p_i) = 1,2 & & i = 7 \\ M_0(p_i) = 0 & i = the \quad rest \;, \quad and & i \le 11 \end{bmatrix} \cdot$$

The demand sent out by ultimate customers will be supplied after transitions: $t_1[0,1], t_2[1,2], t_9[1,4], t_{12}[1,2]$. According to the execution time of transitions, we can calculate the minimum and maximum completion time, and they are $[3,9]$.

(3)Only secondary wholesalers keep inventory

Under grid environment, the marking of Petri nets in the case that only secondary wholesalers keep inventory is

$$M_0 = \begin{bmatrix} M_0(p_i) = 1 & i = 1 \\ M_0(p_i) = 1,2 & i = 8 \\ M_0(p_i) = 0 \quad i = the \quad rest \ , \ and & i \le 11 \end{bmatrix}.$$

The demand sent out by ultimate customers will be supplied after transitions: $t_1[0,1], t_2[1,2], t_9[1,4], t_{12}[1,2]$. According to the execution time of transitions, we can calculate the minimum and maximum completion time, and they are $[3,9]$.

(4)Only retailers keep inventory

Under grid environment, the marking of Petri nets in the case that only retailers keep inventory is

$$M_0 = \begin{bmatrix} M_0(p_i) = 1 & i = 1 \\ M_0(p_i) = 1,2 & i = 9 \\ M_0(p_i) = 0 \quad i = the \quad rest \ , \ and & i \le 11 \end{bmatrix}.$$

The demand sent out by ultimate customers will be supplied after transitions: $t_1[0,1], t_2[1,2], t_9[1,4], t_{12}[1,2]$. According to the execution time of transitions, we can calculate the minimum and maximum completion time, and they are $[3,9]$.

(5)Only manufacturers keep inventory

Under grid environment, the marking of Petri nets in the case that only manufacturers keep inventory is

$$M_0 = \begin{bmatrix} M_0(p_i) = 1 & i = 1 \\ M_0(p_i) = 1,4 & i = 5 \\ M_0(p_i) = 0 \quad i = the \quad rest \ , \ and & i \le 11 \end{bmatrix}.$$

The demand sent out by ultimate customers will be supplied after transitions: $t_1[0,1], t_2[1,2], t_5[1,2], t_{12}[1,2]$. According to the execution time of transitions, we can calculate the minimum and maximum completion time, and they are $[3,7]$.

(6)All the warehouses keep no inventory

Under grid environment, the marking of Petri nets in the case that all the warehouses keep no inventory is

$$M_0 = \begin{bmatrix} M_0(p_i) = 1 & i = 1 \\ M_0(p_i) = 0 \quad i = the \quad rest \ , \ and & i \le 11 \end{bmatrix}.$$

The demand sent out by ultimate customers will be supplied after transitions: $t_1[0,1], t_2[1,2], t_3[1,2], t_4[1,5], t_5[1,2], t_{12}[1,2]$. According to the execution time of transitions, we can calculate the minimum and maximum completion time, and they are $[5,14]$.

5. Results

Based on the model above, we can compute the time needed under traditional mode. Analysis of supply chain information integration under traditional mode can be found in related references[2,7]. The results are illustrated in Table 1.

Table 1. Efficiency comparison between traditional mode and grid environment under different situations

Situations	Traditional mode	Grid environment	dispersion
Intermediaries at all levels keep inventory	[5,13]	[3,7]	[2,6]
Only primary wholesalers keep inventory	[7,25]	[3,9]	[4,16]
Only secondary wholesalers keep inventory	[6,19]	[3,9]	[3,10]
Only retailers keep inventory	[5,13]	[3,9]	[2,4]
Only manufacturers keep inventory	[9,13]	[3,7]	[6,24]
All the warehouses keep no inventory	[11,38]	[5,14]	[6,24]
average	[7.2,23.2]	[3.3,9.2]	[3.9,14]

As can be seen from Table 1, comparing with the supply chain under traditional mode, the supply chain under grid environment has great advantage in responding to the demand of ultimate customers, and it is twice as efficient as the traditional supply chain. Therefore, the application of grid in supply chain has a huge space for development.

6. Conclusion

The application of grid technology in supply chain management will greatly improve the operational efficiency of the supply chain. The results show that the supply chain under grid environment is twice as efficient as the traditional supply chain. However, the paper only studies the efficiency of supply chain under grid environment.

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